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PATENT SPECIFICATION

(11) 1 453 978

(21) Application No. 12650/73 (22) Filed 15 March 1973
(23) Complete Specification filed 15 March 1974
(44) Complete Specification published 27 Oct. 1976
(51) INT CL² H02N 11/00; H01L 41/00
(52) Index at acceptance H2A 1T2B
(72) Inventors GORDON CHARLES JOYCE,
GORDON JAMES RAE and
GORDON CAIRNS WILSON

(19)

(54) LINEAR STEPPER MOTOR

(71) I, SECRETARY OF STATE FOR DEFENCE, LONDON, do hereby declare the invention, for which I pray that a patent may be granted to me, and the method by which it is to be performed to be particularly described in and by the following statement:—

The invention relates to linear stepper motors.

One type of such motor is described in Figure 1 of U.K. Patent No. 1,261,523 and comprises a piezo electric cylinder with magnetic clamps at both ends which rest in an iron vee block. Application of an electric voltage to the cylinder when one end is clamped to the vee block causes the unclamped end to move a small controlled amount, typically between 0.01 and 5 microns for a 1'' long cylinder. Magnetic clamps are well known and clamp two surfaces together by magnetic attraction either from an electro-magnet, or a permanent magnet which can be de-energised electrically for short periods.

According to this invention a linear stepper motor comprises a tube of piezo electric material containing liquid between a rigid end wall and a flexible diaphragm or seal, the tube being provided with electrodes for applying a voltage across the tube walls to vary its length, a first magnetic clamp attached to the tube, a second magnetic clamp connected to the diaphragm or seal, a shaped bed supporting both magnetic clamps, the arrangement being such that application of an electric voltage through the electrodes to the piezo electric tube causes variation in the length and diameter of the tube with a consequential variation in the volume of the enclosed space in the tube and hence axial movement of the diaphragm or seal and its connected second magnetic clamp when the first clamp is clamped to the shaped bed.

In one form of the invention a rod is carried centrally inside the tube with one end connected to the flexible diaphragm and to the second magnetic clamp and with the other end inside the tube and carried by a flexible support to provide axial alignment of the rod and second magnetic clamp.

Preferably the clamps are supported in a vee shaped bed, and the tube is a cylindrical tube.

The invention will now be described by way of example only in the accompanying drawings of which:

Figures 1 and 2 are end and longitudinal section views of a stepper motor;

Figures 3, 4, 5 are longitudinal sectional views of part of other forms of motor.

As shown in Figures 1, 2 a motor comprises a cylindrical tube 1 of piezo electric material carried between a first and a second magnetic clamps 2, 3 which are slidable in a vee shaped groove in an iron bed 4. The inside and outside surfaces 5, 6 of the cylinder 1 are silvered to provide electrodes. One end of the cylinder is closed by a rigid end wall 7 provided with a filling orifice and plug 8. The other end of the cylinder is closed by a thin flexible metal diaphragm 9 carried by an end cap and spaced apart from the electrode 5. Inside the cylinder is a rod 10 having one end 11 carried by a perforated flexible support 12 and its other end carried by the flexible diaphragm with a spigot 13 projecting through the diaphragm for attachment to the second magnetic clamp 3. The first magnetic clamp 2 is attached to the rigid end wall 7. Alignment of the two clamps is assisted by the rod 10 being carried by two spaced supports, i.e. the diaphragm 9 and support 12.

The inside of the cylinder 1 is filled with hydraulic fluid 14 e.g. silicone oil. A flexible electric lead 17 is soldered to the inner surface 5 and to a terminal 15 which passes through a sealed hole in the rigid end wall 7. Another electric lead and terminal 16 is soldered to the outer surface 6.

In operation to move the cylinder 1 along the bed 4 to the right as shown in the drawing, the first magnetic clamp 2 is claimed to the bed 4 in a well known manner, whilst the second magnetic clamp 3 is free to slide. Application of a suitable

voltage between the inside and outside surfaces 5, 6 of the cylinder 1 causes a decrease in length with a consequential increase in diameter and hence a decrease in volume inside the cylinder 1. This causes the flexible diaphragm 9 to bulge outwards and thus move the rod 10, flexible support 12 and second magnetic flamp 3 to the right. The second magnetic clamp 3 is then clamped to the bed 4 and the first magnetic clamp 2 is unclamped from the bed 4. The voltage applied to the cylinder 1 is then removed permitting the cylinder 1 to relax to its original length and if desired the first magnetic clamp 2 reclamped to the bed 4. The cylinder 1 can also be moved to the left as shown in the drawing in a similar manner. Any number of step movements can be made by the motor by repeating the operations noted above. The voltage applied to the cylinder 1 may increase its enclosed volume in which case the rod 10 and second clamp 3 move to the left, i.e. the reverse of the above.

The amount of movement of the rod 10 may be varied by varying the voltage applied to the cylinder 1 typically up to 2.5 Kv and movement typically up to 100 microns may be achieved with a 1'' long cylinder. The amount of movement is partly determined by the relative proportions of cylinder 1 dimensions and the diameter of the flexible diaphragm 9.

The magnetic clamps 2, 3 may use permanent magnets which are selectively deenergised by electro magnets, or electro magnets as required.

In a modification (not shown) to Figures 1, 2 a third magnetic clamp is provided and is attached to the end of the cylinder 1 carrying the flexible diaphragm between the first and second magnetic clamps.

This third clamp allows the motor to be stepped in a large increments (e.g. up to 100 microns) as described above and also allows small incremental steps (e.g. 0.01 microns) by using the changes in length of cylinder 1 with applied voltage in a manner similar to that described in U.K. Patent 1,261,523. Thus for small movements the first and second clamps 2 and 3 remain unclamped whilst the third clamp is clamped to the bed 4. Application of an electric voltage to the terminals 15 and 16 causes a change in the length of cylinder 1 and consequently moves the first magnetic clamp 2 the required small step.

Figure 3 shows a part of another form of stepper motor. As shown a piezo electric cylinder 20 is silvered internally and externally to provide electrodes 21, 22. One end of the cylinder is closed by a cast expoxy resin adhesive wall 23 incorporating a steel insert 24 and filler plug 25 through which the motor is filled with oil 26. Inside the cylinder 20 is an inner casing 27 attached to the cylinder 20 by epoxy resin adhesive 28. The inner casing 27 is sealed by a phosphor bronze flexible diaphragm 29 and carries a sleeve 30 which serves to locate two metal spring spiders 31, 32. These spiders 31, 32 hold a connecting rod 33 which can be adjusted axially to cause a ball 34, mounted on its inner end, to press against the diaphragm 29 by distortion of the spiders and diaphragm. First 2 and second 3 magnetic clamps are attached to the cylinder 20 and connecting rod 33 where indicated by broken lines.

In operation, application of a suitable voltage to the electrodes 21, 22 causes a reduction in the internal volume of the cylinder 20 which results in a deflection of the diaphragm 29 and a consequential movement of the connection rod 33 away from the filler plug 25. Movement of the first and second magnetic clamps 2, 3 is as described with reference to Figures 1, 2.

Figures 4 shows another form of motor. A piezoelectric material cylinder 37 provided internally and externally with electrodes 38, 39 is closed at one end with a cast wall 40 of expoxy resin incorporating a steel insert 41 and filler plug 42 through which the cylinder is filled with oil 43.

An inner steel cylinder 44 is fixed inside the cylinder by an epoxy resin wall 45. Two rubber or plastic ring shaped seals 46, 47 are glued, with cyanoacrylate adhesive, in the inner cylinder 44 to support a connecting rod 48 which is itself glued to the rings 46, 47. First 2 and second 3 magnetic clamps are attached to the cylinder and connecting rods where indicated by broken lines.

In operation application of a suitable voltage to the electrodes 38, 39 causes a reduction in the internal volume of the cylinder 37 and results in a movement of the connecting rod 48 away from the filler plug 42. The rubber 46, 47 deform to allow movement of the connecting rod 48. On removal of the voltage the cylinder returns to its original shape and the rod returns inside the cylinder. This construction is not so accurate as those of previous Figures since there is a certain amount of creep of the rubber seals 46, 47.

Figure 5 shows a simple form of motor comprising a piezo electric material cylinder 50 provided with internal and external electrodes 51, 52. One end of the cylinder 50 is closed by a cast epoxy resin plug 53. Inside the cylinder 50 two rubber O ring shaped seals 54, 55 are glued, spaced apart as shown. A hollow connecting rod 56 is located inside the cylinder 50 and glued to the rings 54, 55. A vent hole 57 is provided in the connecting rod 56 between the rings 54, 55. The motor is filled under vacuum with

oil 58 through the hollow rod 56, and after filling, a sealing washer 59 and plug 60 are tightly fixed in the end of the rod 56. First 2 and second 3 magnetic clamps are indicated by broken lines.

In operation a suitable voltage is applied between the electrodes 51 and 52 and this causes a reduction in the internal volume of the cylinder 50. As a result the incompressible oil 58 forces the rod 56 (and second magnetic clamp) an amount out of the cylinder 50. Upon removal of the voltage the cylinder 50 returns to its original dimensions and rod 56 retracts inside the cylinder 50.

WHAT I CLAIM IS:—

1. A linear stepper motor comprising a tube of piezo electric material containing liquid between a rigid end wall and a flexible diaphragm or seal, the tube being provided with electrodes for applying a voltage across the tube walls to vary its length, a first magnetic clamp attached to the tube, a second magnetic clamp connected to the diaphragm or seal, a shaped bed supporting both magnetic clamps, the arrangement being such that application of an electric voltage through the electrodes to the piezo electric tube causes variation in the length and diameter of the tube with a consequential variation in the volume of the enclosed space in the tube and hence axial movement of the diaphragm or seal and its connected second magnetic clamp when the first clamp is clamped to the shaped bed.

2. A linear stepper motor as claimed in claim 1 wherein a connecting rod is supported by the diaphragm and a flexible support or seal spaced apart along the connecting rod inside the tube.

3. A linear stepper motor as claimed in claim 2 wherein the connecting rod, the diaphragm or seal and the flexible support are mounted in an inner casing or cylinder which is itself fixed inside the tube of piezo electric material.

4. A linear stepper motor as claimed in claim 3 wherein the connecting rod is carried by two metal spiders.

5. A linear stepper motor as claimed in claim 2 wherein the diaphragm or seal and flexible support for the connecting rod are two rubber or plastics rings.

6. A linear stepper motor as claimed in claim 1 wherein two magnetic clamps are connected to the tube of piezoelectric material, one clamp adjacent the end carrying the rigid end wall, and one clamp adjacent the end remote from the rigid end wall.

7. A linear stepper motor constructed, arranged, and adapted to operate substantially as hereinbefore described with reference to Figures 1 and 2 of the accompanying drawings.

8. A linear stepper motor constructed arranged, and adapted to operate substantially as hereinbefore described with reference to Figure 3 of the accompanying drawings.

9. A linear stepper motor constructed, arranged, and adapted to operate substantially as hereinbefore described with reference to Figure 4 of the accompanying drawings.

10. A linear stepper motor constructed, arranged, and adapted to operate substantially as hereinbefore described with reference to Figure 5 of the accompanying drawings.

J. B. EDWARDS,
Chartered Patent Agent,
Agent for the Applicant.

Printed for Her Majesty's Stationery Office by the Courier Press, Leamington Spa, 1976.
Published by the Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.

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2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*
Sheet 1

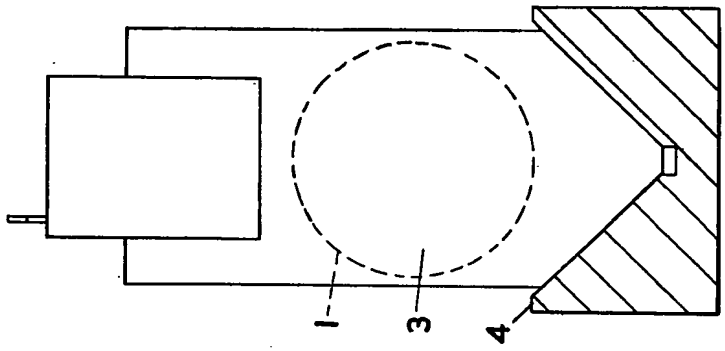

FIG. 1.

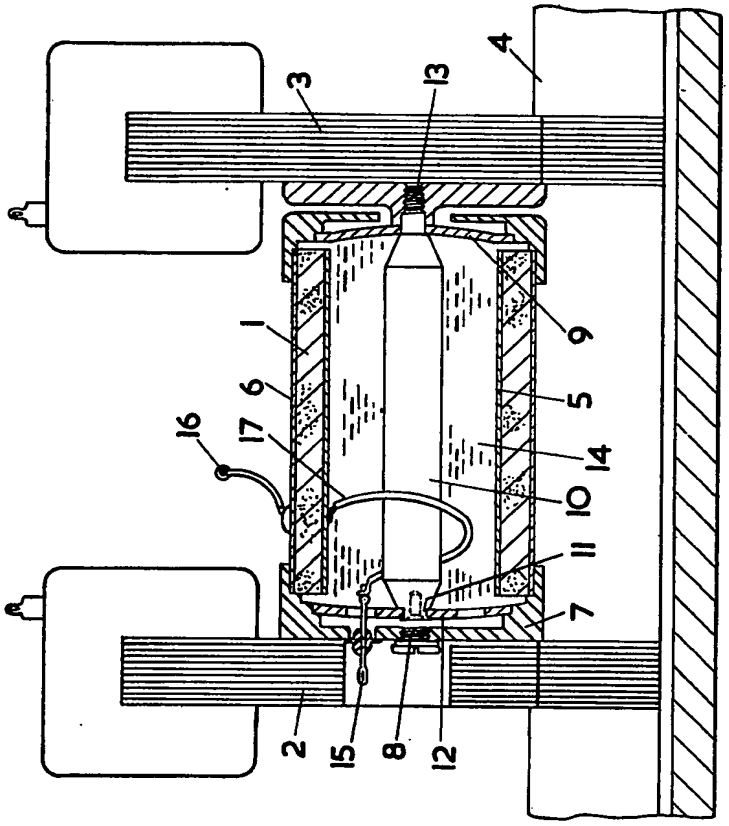

FIG. 2.

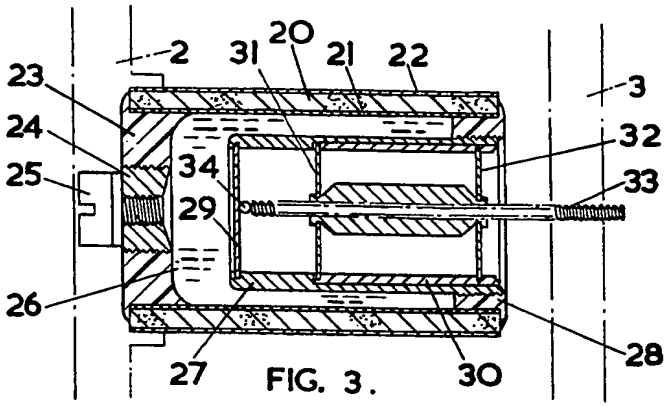

FIG. 3.

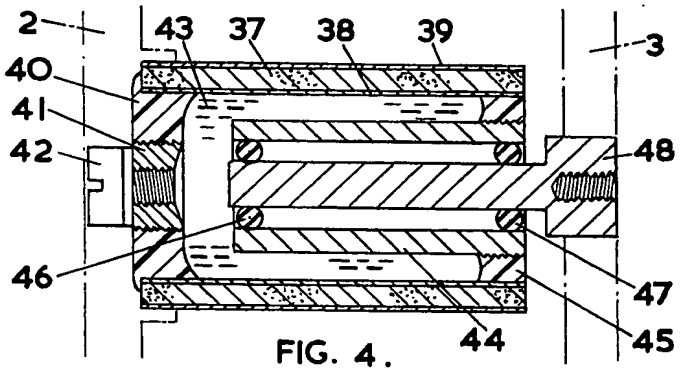

FIG. 4.

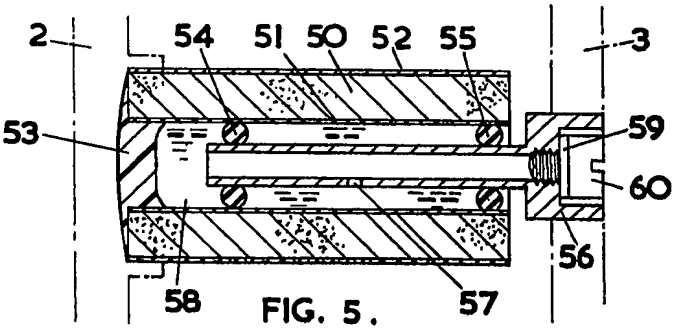

FIG. 5.